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Quantification of the Configuration Factor in Class I and II Cavities and Simulated Cervical Erosions

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Abstract - *The configuration factor of adhesive cavities is defined as the ratio of the restoration's bonded to unbonded (free) surfaces. Such a configuration factor was described, on ideal cavities, as having a potential value in predicting the behaviour of the restorations, because it is related to the restoration's capacity for relieving stress by flow. The aim of this study was to measure the configuration factor value for real Class I and II cavities and simulated cervical erosions prepared in molars. Ten Class I, five Class II cavities and seven cervical erosions were analysed using a computerised digitising system. The configuration factor values found were 4.03 ±0.33 for Class I cavities, 1.85±0.59 for Class II cavities and 1.10±0.09 for simulated cervical erosions ($P<0.01$).*

KEY WORDS: Dental cavity preparation; Configuration factor; Dental restoration, permanent; Composite resins

INTRODUCTION

A clinically successful composite resin restoration is based initially on achieving adhesion between the restorative materials and tooth structure. Resin/enamel adhesion is a well established procedure. However, long term adhesion to dentine with current adhesives has been less thoroughly researched .

Proper adhesion requires mechanical interactions and/or chemical adhesion at the interface between the dental substrate and the restorative material. All current restorative resins shrink during curing, producing internal stresses. This polymerisation shrinkage will produce gaps in the interfacial contact if the adhesive strength is exceeded[1-3].

What occurs at the interface between the tooth and the restorative material during polymerisation is a complex process[4]. Polymerisation contraction induces stress; if this stress exceeds the elastic limit of the composite resin, plastic deformation occurs. During the early phases of polymerisation the elastic limit is still low and plasticity is not opposed to stress. The internal structure of the composite is not damaged since lengthening polymer chains can still change their position and orientation. This deformation is known as flow.

As the resin continues to cure, contraction and flow decrease gradually as hardness increases. This results in a stress increase that causes loss of adhesion and bond failures. These stresses are sufficient to produce cohesive failures in both the restoration and the enamel[5].

First flow and later hygroscopic expansion are the most important factors that release the polymerisation contraction stresses[6,7].

The magnitude of flow (i.e., plastic deformation) depends on the type of composite resin and the cavity configuration. As the bonded surface increases, flow is severely diminished, and the contraction stresses can exceed the adhesion strength[2]. It is clear, then, that the maintenance of interfacial adhesion depends, among many other factors, on the tri-dimensional configuration of the cavity[8]. This configuration is defined by the configuration factor, C, determined by the equation

$$C = \frac{\text{total bonded surface}}{\text{total unbonded surface}}$$

Different investigators have suggested different C values, often based on approximated or unrealistic values[1,2,4,8]. The aim of this work is to determine the C value on Class I and II cavities and simulated cervical erosions prepared in human molars.

MATERIAL AND METHODS

Twenty-two intact caries free mandibular molars stored in 10% formalin were assigned to one of three groups. Mandibular molars were selected to avoid the presence of the *cresta oblicua*. Group A contained ten teeth (five first molars, five second), group B five (two first molars, three second) and group C seven (three first molars, four second). One cavity was prepared in each, as follows:

Class I and Class II cavities were prepared in groups A and B, respectively, using a 330 bur (Komet), at high speed and under abundant water cooling.

Class I cavities (group A) were prepared in the principal occlusal grooves at least as deep as the length of the bur (1.6mm), and its shape and contour depended on the occlusal anatomy of the molar. In all preparations the occlusal perimeter was greater than basal perimeter. Inlay type cavities were made to ease impression making and the design included all fissures and grooves.

Class II cavities (group B) were prepared in two boxes. One, occlusal with the same criteria as Class I cavities (group A). Two, a proximal box was prepared with, at least, an axial wall of 1 mm of height, and always affecting the mesial aspect of the tooth, to avoid including the disto buccal cusp when present (two cases). The isthmus was widened so as to achieve a smooth transition between occlusal and proximal boxes.

Cervical erosions (group C) were simulated by cutting with a diamond disk mounted in a handpiece. Two flat

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†BDS

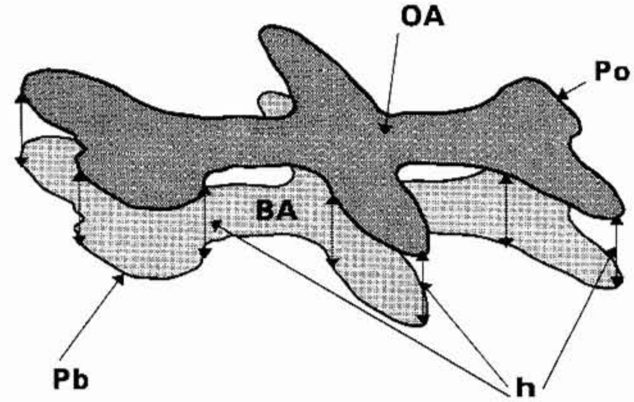

Figure 1. *Parameters measured for calculation of configuration factors for Class I restorations. OA: occlusal access area. Po: Occlusal perimeter. BA: basal area. Pb: basal perimeter. h: height.*

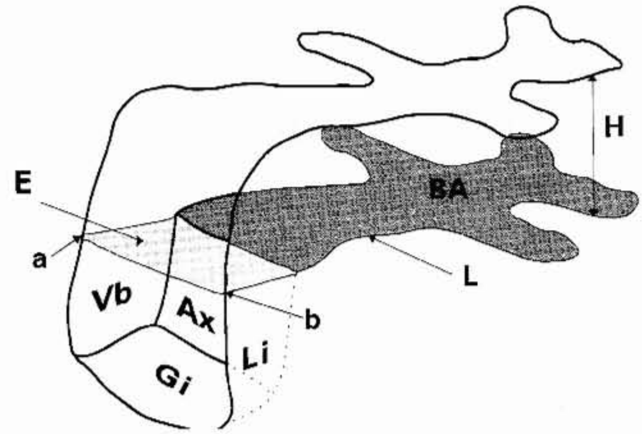

Figure 2. *Parameters measured for calculation of bonded surface area in Class II restorations. BA: basal area. h: height. L: length of the boundary of the area BA+E minus length ab. E: entrance to the proximal box. a and b: points of intersection of cavosurface line and basal plane.*

surfaces were prepared in the cervical zone, affecting crown and root. Both surfaces formed an interfacial angle of 160°. The range of the depth of the erosion was 0.7-1.4 mm.

Impressions were made of group A and B cavities with addition-cured silicone impression material with a two-step technique (Express STD putty material, firmer set, and light body, regular set fluid material. The zone of the impression that reproduced the cavity was cut off all impressions.

Images of all the surfaces to be measured were obtained and digitised with a camera (JVC CCD) and analysed with an image analysis system (VIDS IV System) provided with a digitising tablet (Summagraphics Corp. model MM 1103). Calibration was set to the equivalence 0.0914 mm/pixel. The following measurements were made:

Class I cavities: (Group A). In the teeth, the occlusal area (OA) and occlusal perimeter (Po) of cavity access were measured (*Figure 1*). In the impression: basal area (BA), basal perimeter (Pb), and a number (n) of heights (h) at buccal and lingual aspects of the cavity. The number (n) of heights was never less than fourteen, seven on each face. Mean value of height is calculated as follows:

$$H=\frac{h_n}{n}$$

In this group, the total bonded surface area was calculated with the formula:

$$\text{Total bonded area} = BA + \{Pb*H\} + \frac{(Po-Pb)*H}{2}$$

where the first part is the basal area (BA), the second is the area of the rectangle formed by the basal perimeter (Pb) and the average height (H), and the third part is the area of the triangle formed by the average height (H) and the difference between the occlusal and the base perimeter. The configuration factor was calculated with the formula

$$C=\frac{BA + \{Pb*H\} + \frac{(Po-Pb)*H}{2}}{OA}$$

Class II cavities: (Group B). The cavities were divided into two sections (occlusal and proximal) by a horizontal - 'basal' - plane continuing the surface of the base of the occlusal cavity. This plane defines two points (a and b, *Figure 2*) when intersecting the cavosurface line. The impressions were sectioned with a sharp blade along this plane. In the occlusal portion of the impression, the following measurements were obtained: basal area (BA) (the pulpal floor of the occlusal cavity); a number (n) of heights (h) that, in the same way as in the Class I cavities measurements, permitted us calculate the average height (H) the area of the entrance (E) to the proximal box; and a length (L), being the length of the boundary of the area BA+E deducting the distance from a to b. In the proximal portion the areas of the axial (Ax), lingual (Li), buccal (Vb) and gingival (Gi) walls were measured.

On the teeth, the area of the occlusal access (OA) was measured reaching proximally the points in which the occlusal face turned into proximal. These points were placed where the edge on top of the marginal ridge reached the cavosurface line. The external area of the proximal face was divided in sub-areas (R1, R2 and Px) (*Figure 3*). Px sub-area goes from line ab to gingival margin. R1 and R2 relative dimensions depend on the convexity of the surface surrounding the contact area as they are calculated to approximate that curved surface to a flat one.

For Class II cavities, the configuration factor was

$$C=\frac{Gi + Li + Vb + Ax + BA + [H*L]}{Px + R1 + R2 + OA}$$

The area of the adhesive walls of the occlusal portion was calculated as if it was a rectangular area, multiplying length of its base (L) by the average height (H).

Cervical erosions. (Group C): in each specimen the total area of the restoration was measured, and assigned to the free -unbonded- surface (FA). It was calculated as a flat surface because the curvature was negligible. The bonded areas were measured by positioning the tooth so that both the occlusal (OA) and cervical (CA) cavity surfaces were digitised perpendicular to the camera. The C value was obtained by the formula:

$$C=\frac{OA+CA}{FA}$$

RESULTS

Results of measurements of the cavities are detailed in *Tables 1* (Group A), *2* (Group B) and *3* (Group C), expressing in each one all the measurements obtained

Table 1. *Parameter measurements for the Class I cavities in group A. Lengths expressed in mm. and areas in mm².*

	Cavity preparation									
Parameter	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
OA	6.679	9.968	11.364	12.749	8.003	16.252	7.031	11.113	10.208	10.552
Po	11.829	13.833	15.858	16.731	11.778	19.521	10.124	12.604	14.603	14.800
BA	5.407	7.107	7.001	9.489	5.903	16.718	7.053	10.354	10.407	9.505
Pb	11.541	13.304	13.861	14.602	10.305	18.500	9.960	12.070	13.870	13.614
H	1.822	2.332	2.283	2.404	2.586	2.586	2.240	2.797	2.218	2.227

OA: occlusal area, Po: occlusal perimeter, BA:basal area, Pb: basal perimeter, H: average values of height

Table 2. *Parameter measurements for the Class II cavities in group B. Lengths expressed in mm and areas in mm²*

	Cavity preparation				
Parameter	*1*	*2*	*3*	*4*	*5*
E	7.582	11.778	5.751	9.092	11.905
Gi	5.994	8.422	4.734	6.759	6.889
Li	4.422	6.440	2.611	3.893	4.281
Vb	4.987	5.800	1.846	4.919	4.184
Ax	3.839	4.486	1.911	5.585	4.564
BA	14.407	13.718	6.321	12.636	8.277
L	22.156	20.978	14.597	19.781	14.621
H	2.184	2.575	1.954	2.984	2.738
R1	5.198	7.458	3.577	10.921	10.620
R2	2.666	8.928	3.626	8.862	n.c.
Px	5.894	8.947	4.081	11.468	8.462
OA	21.268	28.853	16.020	18.003	22.858

E: entrance to proximal box, Gi: gingival wall, Li: lingual wall, Vb: buccal wall, Ax: axial wall, BA: basal area, L: perimeter of area resulting of BA+E, deducting the distance ab, H: average values of heights, R1, R2: ridge areas, Px: proximal area, OA: occlusal area. Area expressed in mm², lengths in mm. n.c.: not calculated (proximal face with little convexity).

Table 3. *Parameter measurements for the cervical erosions in group C. Areas, expressed in mm².*

	Simulated cervical erosion						
Case	*1*	*2*	*3*	*4*	*5*	*6*	*7*
FA	16.151	9.348	19.921	13.513	12.427	26.285	16.823
OA	10.245	6.183	11.434	9.117	8.140	18.145	7.332
CA	7.057	4.354	9.452	6.241	6.857	9.896	9.771

FA: free (unbonded) area, OA: occlusal bonded area, CA: cervical bonded area.

in each specimen. Calculated configuration factors, with their means and standard deviations are detailed in *Table 4*.

DISCUSSION

In our specimens the size of the cavities is widely variable. It can be denoted by the difference, for instance, between the occlusal area (OA, *Figure 1*) of specimen one (6.679 mm²) and specimen four (12.749 mm²) of group A (Class I cavities) or by the difference between basal area (BA, *Figure 2*) of specimens three (6.321mm²) and four (12.636 mm²) of group B (Class II cavities). This can be explained by the anatomical variability. Such a wide range of sizes does not alter the significance of the study because values found for the configuration factor (i.e. 4.03±0.33 for Class I cavities, 1.85±0.59 for Class II cavities and 1.10±0.09 for simulated cervical erosions ($P<0.01$)) are well defined for each type of cavity.

Our intention was to approach to real clinical situations of impossible systematisation, as they depend on, among other factors, formation, instrumentation, experience and skills of the clinician, on anatomical and biological variability, and on the presence and importance of pathology in each case. For these reasons, total standardisation of the design of the cavities seems inappropriate for the aim of the study. Other authors[9] have measured the occlusal area of preventive resin restorations in mandibular first permanent molars (n = 33), obtaining an average(std) area of 9.81 (4.88)mm², which is remarkably similar to the average(std) occlusal area of our group A 10.39(2.69). In their study the lesion was entered, additional caries removed (if necessary), and questionable carious areas of pits and fissures were included in the preparation. It must be pointed out that, in our case, all grooves were included in all cases. The conclusion one can draw is that a 'minimal' preparation is not so different to a more 'classical' one, at least in terms of extension of the occlusal surface. This 'classical' design has the added advantages of moving the cavosurface margins to a zone more easy to manage by the clinician and clean by the patient.

Our way of simulating cervical erosions was chosen because it was the best way found of reproducing flat surfaces, easily measurable, that are still similar to the clinical situation.

In the calculation of the free surface of occlusal boxes (Class I and II) we do not take into account the grooves on the surface. The influence of the configuration factor is most important during polymerisation, when the maximum stress is accumulated in the restoration, supposing

Table 4. *Configurations factor values (c) for all cavity preparations and simulated cervical erosions. Means and standard deviations (STD) of C for each group.*

	Cavity preparation and simulated cervical erosion										
Group	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*AVG (STD)*
A	4.00	3.89	3.60	3.70	4.82	4.05	4.02	4.04	4.11	3.90	4.03 (0.31)
B	2.34	1.771	1.68	1.88	1.63						1.85 (0.26)
C	1.07	1.13	1.05	1.14	1.21	1.07	1.02				1.10 (0.06)

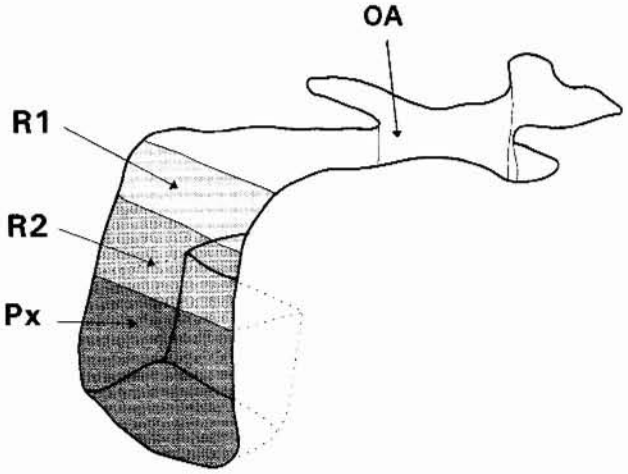

Figure 3. *Parameters measured for calculation of unbonded surface area in Class II restorations. R1 and R2: ridge external subareas. Px: proximal area. OA: occlusal access area.*

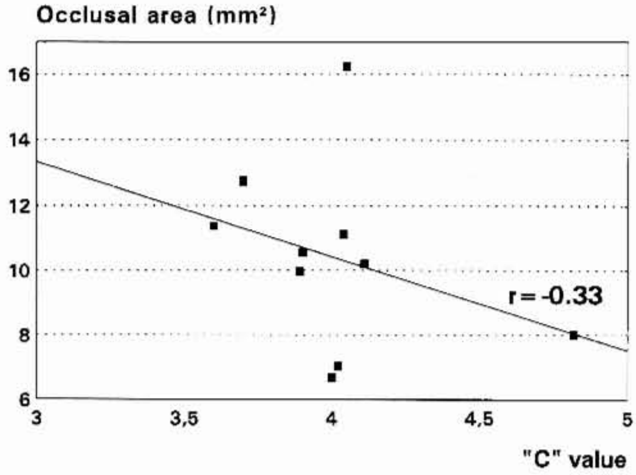

Figure 4. *Relationship between occlusal area and C value, in group A (Class I cavities). r: Pearson's coefficient of correlation.*

the restoration is to be cured as a whole. In this case grooves will be modelled later, when initial polymerisation has taken place and most of the stress has appeared.

With respect to manipulation of resins, it has to be kept in mind that few restorations are placed as a single increment, except inlays. Current incremental techniques mean that each little increment of resin is affected in a different way when placed and cured. Thus, configuration factor values should be understood only as an approximation to reality, and a way of predicting the behaviour of a mass of contracting material. To be closer to reality, partial 'C' values should be calculated for the different increments of resin. Although considerable work has been carried out in this field, it is still difficult to establish what value of C is incompatible with the maintenance of adhesion, since it also depends on other factors.

In our method, we consider curved surfaces as flat ones. This happens with proximal faces (in Class II cavities) and free surfaces in simulated cervical erosions. Although we have tried to approximate the curved surface of the external area of the proximal face of Class II cavities by dividing it into sub-areas (R1, R2 and Px) (*Figure 3*), and although it is clear that this approach is not perfect, it is, in our opinion, better than not considering it.

To date, studies[1,4,8] considering configuration factor are based on ideal approximations to cavities, accepting a geometric -cubical- standard as a pattern. In our study the real dimensions and proportions are considered, being the values found consistently within each type of cavity.

A typical adhesive cavity, such as cervical erosions, has never been measured. The configuration factor of this type of cavity has been approximated as if it was shaped as a Black's Class V cavity. This study quantifies its values using simulated erosions.

In Class I cavities the perimeter of the base of the cavity (Pb) is often greater than that of the occlusal area (Po). Because of our interest in easing the insertion and removal of the impression material in such narrow spaces we have approximated a non-retentive adhesive inlay design. In this aspect, if such cavities were to be restored with esthetic-resin or ceramic-inlays, the value of the configuration factor of the cavity that contains the cement should be 207.74±37.98, allowing a 200µ hiatus, which is the maximum room for the cement layer found in the literature[10,11]. Other authors[12] find a smaller axial discrepancy (17-121µ) that would result in a still larger value of the configuration factor of the space-cavity containing the adhesive cement. It has to be kept in mind that fixation of adhesive rigid restorations (inlays, crowns) requires placement of all the cement in a single step. These are the situations in which the configuration factor is determinant and clearly unfavourable, and make us doubt the future of the adhesive luting material.

According to Feilzer *et al.*,[8] when C > 1, adhesion could not be maintained with conventional adhesives only. With the highly unfavourable values found, we should recommend the use of different types of adhesives or linings[13,14], different resins[15,16], different formulations of resins[17] and/or variations in technique, such as techniques that control the resin's phototropism, as discussed in the works of Donly *et al.*[5]

CLINICAL IMPLICATIONS

The relationship between C values and occlusal area in group A is depicted in *Figure 4*. The correlation factor (Pearson's r) is r=-0.33, meaning that if occlusal area increases (thus speaking of a broader cavity) C value decreases. As the absolute value of r is low, it is not significant and with our data is impossible to assert that the relation is as stated. However, it is reasonable, with the type of cavity used in this experiment, to expect a worse adhesive behaviour for narrower cavities. In addition, in such cases, the use of incremental techniques is difficult due to the very small dimensions involved.

When considering luting of rigid adhesive restorations, the value of the configuration factor of the cavity that contains the cement will reach 207.74±37.98 in the case of a discrepancy of 200µ. It is difficult to understand why, with such an unfavourable C factor, clinical behaviour of these restorations is still reasonable. Possible explanations include: porosity of the luting material which lowers the C value[18], as it adds free surface uniformly distributed, and adhesion is probably better at the margins, as the cavo surface area is the only place where flow can compensate in any way for contraction of the luting material. However that flow is immediately blocked at the surface with the application of light, thereby not participating in any stress relieving in the interior of the extremely shallow cavity that contains the luting cement. In this way the restoration is fixed in place mainly by a collar of superficial adhesive luting cement.

MANUFACTURERS' DETAILS

- Komet, Gebr. Brasseler GmbH, Germany.
- Express, 3M, St. Paul, MN, USA.
- JVC CCD, model TK-870E, Japan.
- VIDS IV System, Analytical Measuring Systems, Cambridge, UK.
- Summagraphics Corp., model MM 1103, USA.

ADDRESS FOR CORRESPONDENCE

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